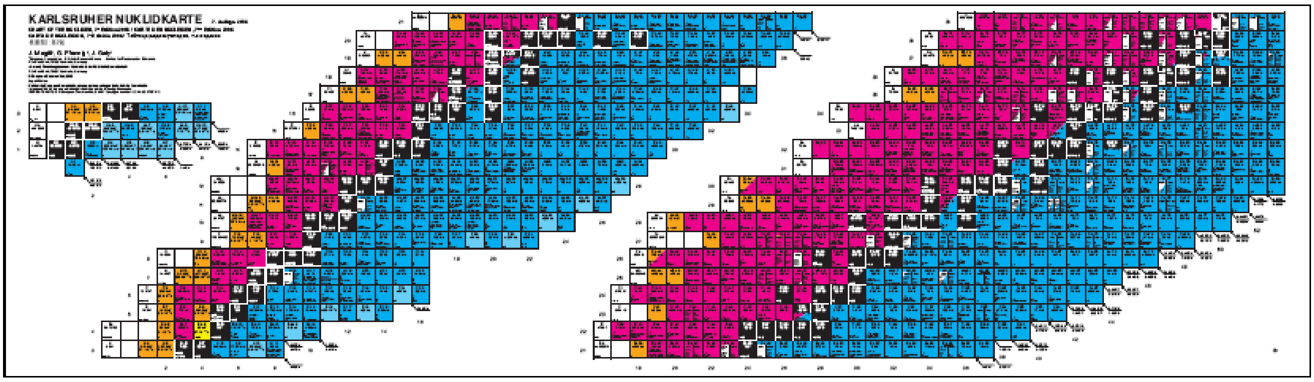
JRC Technical Notes

The Karlsruhe Nuklidkarte Database

Cat. 30 Research Fellow: End of First Year Report

Christophe Normand



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1. Introduction

In this technical note, a comprehensive account of the work carried out at ITU in the first year of my Category 30 Research Fellow position is presented. The contract for this post began on 15th June 2006 with the project title "Karlsruhe Nuclide Chart". The content of this report covers the different parts of the activities devoted to this project. The first part is a summary of the associated actions, whilst the second part concerns the related documents.

2. Translations and brochure

The first task that I was assigned to, was to take care of the translations concerning the explanation booklet accompanying the fold out chart and the text located on the wall-chart. In addition to the four languages used in the 1998 edition [1], German, English, French and Spanish namely, Russian and Chinese were added to this new edition,. After reviewing the French and Spanish ones, I also coordinated the Russian and Chinese ones. These translations can be found in the latest edition of the Nuclide Chart [2].
After the release of the new edition this work is continued as subsidiary task, leading to the online access of the Italian, Korean, Japanese and Romanian translations. Two new ones are waiting: Arabic and Portuguese.

3. The Karlsruhe Nuclide Chart

Nowadays, more and more emphasis is put on the scientific databases and their management as the complexity of technical projects increases significantly and the need of former and trustful data is a prerequisite. A good example of a "long lived" nuclear database is illustrated by the "Karlsruhe Nuclide Chart".
The Karlsruhe Nuclide Chart is a long well known scientific tool of which posters from the various editions can be found on the walls of several nuclear laboratories and will be 50 year old this year. Its principle is to provide to the scientific community the latest available experimental nuclear decay data reported mostly in the international scientific literature. The 7th edition[1] from 2006 follows this concept and makes the synthesis of almost one half-century of work. From 1517 radio-nuclides in 1957 to more than 3650 nowadays, the chart evolved with the successive breakthroughs carried out in this field, i.e. the discovery of a new decay mode or a new element. And it is a striking feature of its long term success; the quality of the provided database recognized worldwide goes together with the establishment of a standard in terms of visualization scheme. The so recognizable pallet knew such a strong enthusiasm that it became an inspiring reference.
Through this depicting of major decay properties, it offers a very useful data set for every single nuclide including half life, decay modes, decay energies, abundances, cross sections, thermal fission yields or atomic weights. As this chart was not developed for a specific purpose and with specific data needs, the presented data are applicable to most fields requiring application of nuclear techniques as medicine, environment protection, radioprotection, astrophysics …
Its established popularity, as well as its great didactic value, constitutes a challenging framework of development for necessary and continuous improvements. In one hand, the number of translations of its vademecum is now up to 10, facilitating its accessibility to a wider number of people. In the other hand, the Karlsruhe Nuclide Chart is beginning to benefit from new technologies with a presence on Internet through the NUCLEONICA

website [3], and by looking in the direction of an electronic edition in order to capitalize the wider knowledge available.

In the proliferation of information linked with the new information technologies, this paper based chart offers a trustful, educative and standardized compilation, evaluation and visualization scheme of nuclear data.

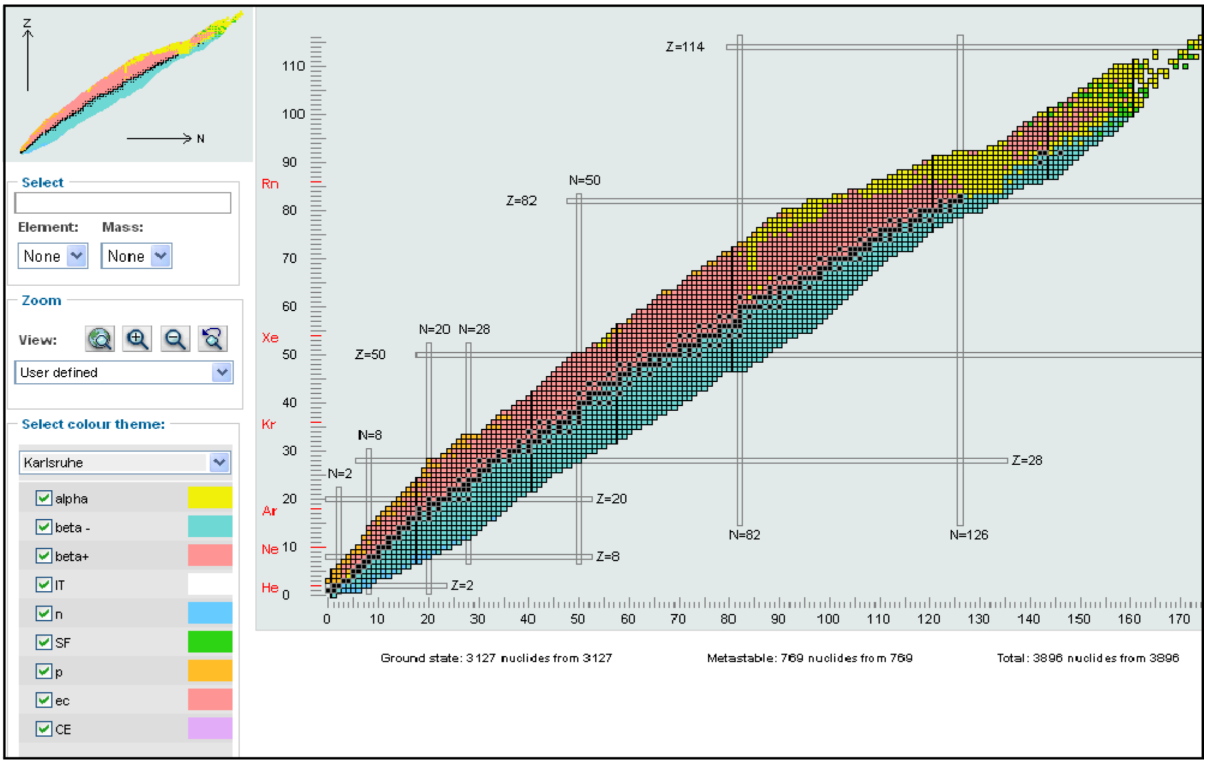


Fig. 1: The "Karlsruhe Nuclide Chart" colour visualization scheme use with the NUCLEONICA website.

3.1 Creation of a related database

The needs for an electronic database are of two kinds; the possibility to have a tool to follow the evolution of the data as well as to make easier new updates of the chart and the development of an electronic version of the chart. In the following section we describe what makes the specificity of such a database and the way to generate it. The keys to success of this "long-lived" paper-based chart, created nearly half a century ago, will be then analyzed. Since its early creation, back in 1947, the chart was developed around two principal axes which largely contributed to make a standard of it.

The first axe consists in the choice of data to be implemented into the chart, with significant attention to their scientific published source. In the nuclear chart of Karlsruhe, the data come predominantly from experimental data confirmed published in international recognized scientific literature. The sophisticated structure on which the paper information is then collected is essential and establishes the link between the raw data and its appreciation by the evaluator. Classification groups of properties in connection with the structure and the decay of nuclei have been developed. We collect firstly the properties relating to the chemical element, i.e. the atomic weight, and the ones concerning the nuclide such as relative abundance or half life, thereafter, the properties directly connected to the decay modes and the transition characteristics, such as relative branching ratios and decay energies

3.2 Structure of the data

Every single nuclide is in the absolute defined by its composition in neutrons and protons. These two numbers are the essential characteristics of it. From the combination of these two numbers some general feature can be defined. Firstly, the isotopes have the same number of protons and described one element, therefore having the same chemical properties. Historically, the discovery of the elements came first; accordingly the naming of the element is connected to their discovery mean.
Another interesting sub grouping consists in defining the isobar. An isobar is constituted of the nuclides having the same number of nucleons. Some standard nuclear data are associated to the isobars and thus are collected in the database, such as the mass distribution fission yields for the thermal fission of both U-235 and Pu-239.

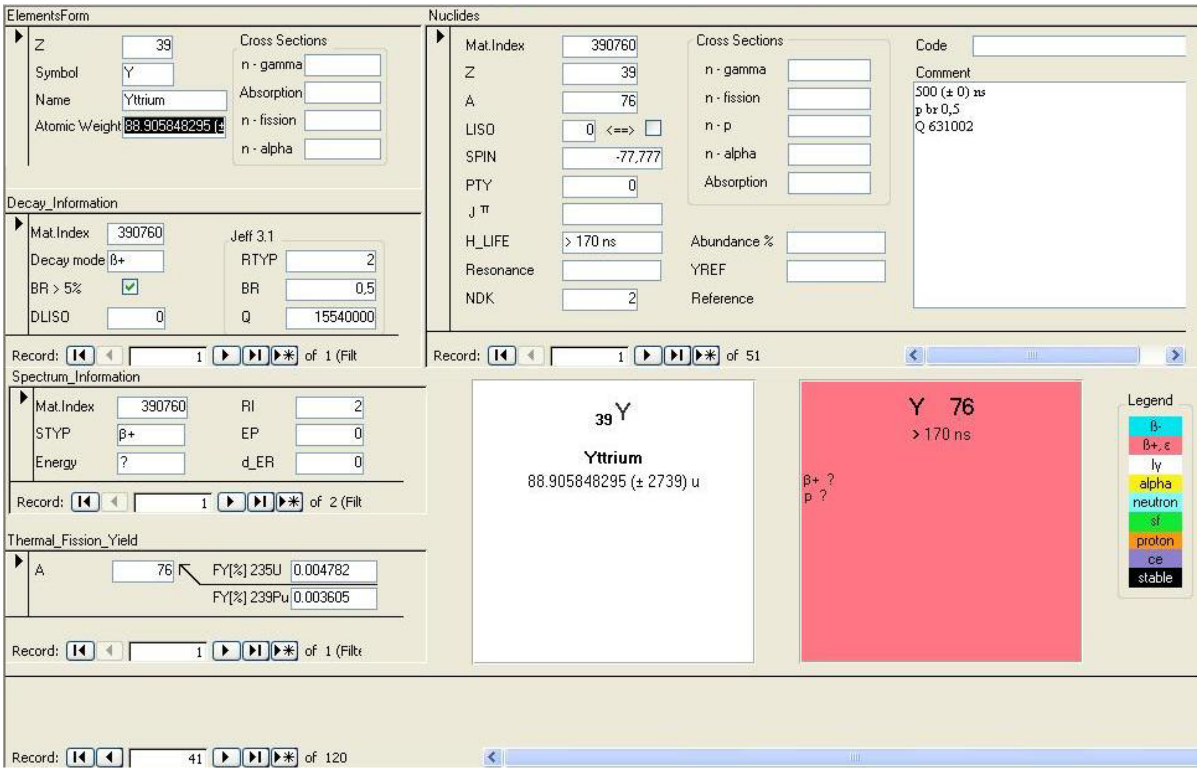


Fig. 2: Screen capture of the KN Database

When creating a new nuclide entry in the database, the first field to be defined is the chemical element of which properties are given in the International Union of Pure and Applied Chemistry (IUPAC) publications. Up to now, 108 elements have been identified.
From this data, the chart shows five different fields: the name of the element, its symbol, its number of protons and its atomic weight, and a cross-section panel.

Each nuclide is coded with a material index in the database, which is displayed in a subfield..
The "nuclide" section gives access to the following information: numbers of protons and neutrons, isomeric state indicator (LISO), spin and parity, half-life, resonance width and abundance. A "reference" and a "comment" fields are also available in the present version. A cross-section entry fields can additionally be filled.

The "decay" section provides information determining the color scheme of the nuclide-box in the chart representation. In this database section, the decay type and its corresponding code, decay branching ratios, Q-value and an indicator on the isomeric state of the daughter nuclide are given.

Spectral decay information can be found in the “spectrum” panel. The main characteristics extracted from the chart are the different decay modes, corresponding classification identifiers and the spectral values associated with the given decay modes. An example of the usefulness of this panel is to easily retrieve gamma radiations emitted for a specific decay mode. It should be noted that spectral information is not provided in any other sections. With the help of a special coding, we provide in this panel the information on the isomeric status of the daughter nuclides is provided.

The major achievement of this first post doc year, was the realization of an electronic database to be used for the future updates of the paper edition and comparison surveys of the collected data with well established nuclear evaluated databases.
The essential purpose of the on-going work on this Karlsruhe Nuclear Chart Electronic Database is to give potential authors a useful tool to assist the publishing future editions. The completion of the database interface and data collection has been completed in the second half of the year 2007 and it’s currently being by another member of the Karlsruhe Nuclide Chart development team for the design of a web interface for on-line access to the data.
The comparison with other evaluated databases has been initiated and interesting observations can already be considered.

4. Dissemination of information

The recognized difficulty to access information on the “Karlsruhe Nuclide Chart” and its dissemination means, led to the identification of business solutions developed during the first year of this post doc activity.
The Nucleonica website is hosting web pages providing basic information on the chart and as well purchase information. A main task allocated to this post doc was to link these web pages to other sites were people are seeking this kind of information. Registration of the Nucleonica website and its related Nuclide Chart pages, resulted satisfactory results in term of visibility. In addition, insert of articles in the Wikipedia online encyclopedia were also made. On the French and English websites were provided links to the Nucleonica web-site besides pieces of information concerning the related material, more particularly an historical overview of the “Karlsruhe Nuclide Chart” (http://wikipedia.net/KarlsruheNuclide Chart).

5. Reference Database

In a first approach, this aspect of the database was disregarded. Nevertheless, intensive work has been initiated during summer 2007 to extend the present database with scientific reference information. R. Dreher has set an access tool, and the earlier references from the previous authors are now being stored with the associated nuclear data. The reference data basing allows assessment of the values from the original publications. When available, a link to an electronic file is provided. The prior access database is now completely incorporated in the new extended one.

6. Collaboration with the JEFF project

One worldwide reference for nuclear data is the JEFF project developed on behalf of the NEA (http://www.nea.net/JEFF). ITU has been part of the JEFF group meeting in the past years, and the present work allowed providing benchmark comparisons of the two products developed by ITU, Nucleonica and the Karlsruhe Nuclide Chart with the JEFF values. Great interest has been expressed on this work by the “JEFF Decay Data” group. Some possible collaboration on the analysis of the discrepancies has been evocated.

7. Nuclides.net Training Courses

Another important activity in the previous year was my involvement in organizing and contributing to the 8th nuclear science training course with Nuclides.net [4]. This course is organized in support of the Commission enlargement policies and is attended primarily by participants from new and candidate countries. My main personal involvement has been the preparation and delivery of a lecture on the "Karlsruhe Nuclide Chart".

8. Outlook

Despite that the work preformed during over this year could not be considered as "pure scientific activity", it has been recognized as an essential and indispensable labour for the future edition release of the Karlsruhe Nuclide Chart, due to be released in 2008. The work devoted to the study, the analysis and the resulting discussions on the available experimental data will without doubt provide new material for the scientific community. Further collaboration with the JEFF group will offer the opportunity to provide them expertise on decay data and to get an increasing role in the development of this reference database.

Bibliography:

1 G. Pfennig, H. Klewe-Nebenius and W. Seelmann-Eggebert, Karlsruhe Nuklidkarte, 6th edition, Forschnungszentrum Karlsruhe, Germany, 1998.

2 J. Magill, G. Pfennig, and J. Galy, Karlsruhe Nuklidkarte, 7th edition, Institute for Transuranium Elements, Germany, 2006.

3 http://www.nucleonica.net/nuclidechart.aspx

Annexes

Mission Report of the participation of Jean Galy and Christophe Normand to the JEFF/EFF working groups on evaluation and data validation and meeting at the CEA/Saclay

The JEFF/EFF working group on evaluation and data validation meeting took place from Monday 20/11/2006 to Wednesday 22/11/2006 at the NEA databank headquarters, Issy les Moulineaux, France. About 50 people followed the meeting, mostly from CEA-France, the IAEA, FZK-Germany and NRG-Netherlands but as well some guess from USA and Israel. Discussions were focused on the status, needs, evaluation, benchmarks and testing, and future releases of the European nuclear data library JEFF-3.1 and the EFF/EAF (European Fusion File/European Activation File).
Interest for the ITU is principally driven by the development of Nucleonica which is using and displaying data from JEFF library, and the join ITU/FZK project on the new edition of the Karlsruhe Chart of Nuclides.

About the JEFF3.1, radioactive decay data (RDD):
Couple of accepted corrections to the actual JEFF-3.1-RDD (of relevance for Nucleonica) file have been discussed and agreed during the meeting.

- A recent measurement of the half-life of ^{79}Se has been achieved: $T_{½} = (3.77±0.19)·10^5$ a. This new value will be taken into account for the next evaluation.

- Correction of the branching ration for spontaneous fission of ^{238}U, which should be $5.46·10^{-7}$ instead of $5.46·10^{-5}$

- The uncertainty on the mean beta energy for the ^{89}Sr decay given in the JEFF-3.1 RDD (233.8 keV) is not correct. It will be corrected to 1.0 keV!

The American competitor evaluation file ENDF/B-VII which is about to be released in December. Technical details are presented in the December edition of Nuclear Data Sheet.

The JEFF report 21: “The JEFF-3.1 Nuclear Data Library” has been published and is available.

The JEFF-3.2 evaluation is to be released by 2008/2009 with photonuclear, activation, proton and deuteron libraries.

ITU participation to the JEFF project:
A presentation (“Nuclear Data Activities at the ITU”) has been presented by Jean Galy and Christophe Normand. The presentation is referenced as a JEFF document JEF/DOC-1153. JEF/DOC are considered as non official papers and are for internal use within the JEFF group, but can nevertheless be requested from the NEA databank.
The talk presented the three main lines of the ITU nuclear data activities:

- The Nucleonica Web-driven Nuclear Science Portal.

- The current status of the high intensity laser nuclear reaction studies carried out by the ITU and its undergoing program for future photo-cross-section-measurements.

- The recent release of the 7th Edition of the Karlsruhe Chart of Nuclides.

Christophe Normand has, during its talk, presented a preliminary study made at the ITU which compares nuclear data from the JEFF-3.1-RDD evaluation file and the data set used in

the latest edition of the Karlsruhe Chart of Nuclides achieved at the ITU. Important discrepancies can be noted in half-lives, modes of decay or actual number of nuclides and isomers. The JEFF evaluation group has shown great interest in the presented comparison and has expressed its will that the ITU goes further in its investigations. Mark Kellet from the IAEA, who would like to release the new version of the JEFF3.1-RDD dataset by the time of the next meeting, asked the ITU if we could provide him a list with identification of the main discrepancies between the two above mentioned datasets.
On the other hand, Hans Henriksson (NEA) has expressed the possibility of a future collaboration NEA/ITU on the bases of the Nucleonica (ITU) and Janis (NEA) packages.

Visit at the CEA/Saclay:
Meeting has been held at the CEA-Saclay/DSM/DRECAM/SPAM with our collaborators at the UHI10 laser facility laboratory. The laser is being upgraded at the present moment time to 50TW and should reach 100TW in a second upgrade step planned by the end of 2007.
ITU will send an experimental proposal, by beginning of the year 2007, for access to the upgraded laser mid-2007. This proposal will be based on the recent experimental results obtained during the June 2006 campaign at the UHI10 by ITU and collaborators, and the Monte-Carlo calculations under-going at the ITU to elaborate an experimental protocol for measurement of photo-nuclear cross-section.

Mission Report of the participation of Jean Galy and Christophe Normand to the JEFF/EFF working groups on evaluation and data validation

The JEFF/EFF working group on evaluation and data validation meeting took place from Monday 04/06/2007 to Wednesday 06/06/2007 at the Escale Oceania Hotel, Aix en Provence, France. About 50 people followed the meeting, mostly from CEA-France, the IAEA, FZK-Germany and NRG-Netherlands but as well some guest from USA. Discussions were focused on the status, needs, evaluation, benchmarks and testing, and future releases of the European nuclear data library JEFF-3.1 and the EFF/EAF (European Fusion File/European Activation File).

Interest for the ITU is principally driven by the development of Nucleonica which is using and displaying data from JEFF library, and the joint ITU/FZK project on the new edition of the Karlsruhe Chart of Nuclides.

About the JEFF3.1, radioactive decay data (RDD):

The most important part of this session was dedicated to the work on fission product yields from R. Mills and the decay data from activation products and heavy elements and actinides. It has been also discussed the next release of the JEFF-3.1.1-RDD decay data library and the associated documentation (JEFF report 20). These two documents are of relevance for Nucleonica and the next edition of the Karlsruhe Nuclide Chart.)

Most of rest of the discussions dealt with benchmarking and corrections to JEFF-3.1. The status of new evaluations for various nuclides was also considered with some feedback advising former data.

The feedback of users of the database for applied calculations was appreciated as the same time that it focused the lack of data in region of special interest, i.e. proton therapy with Institut Curie and the Orsay Proton Therapy Center, or reactor dosimetry.

One recent target of the JEFF project is the development of covariance matrices to give access to a better understanding of the results given by the calculations using JEFF-3.1. A dedicated effort from the CEA, and especially of the CEA Cadarache group, was presented with various talks including Kalman filtering techniques and the new Conrad software. It has been mentioned that these results should not be available with possible dates for the new release of JEFF-3.2.

No date has been yet decided for the release of the JEFF-3.2 evaluation with photonuclear, activation, proton and deuteron libraries.

NEW BOOKLET TRANSLATIONS

1. Italian translation (H. R. Tedeschi)

2. Japanese translation (Dr. K. Uozomi)

3. Korean translation (Dr. P. Lee)

Spiegazione della carta dei nuclidi

Generalitá

In questa carta, ogni nuclide messo in evidenza sperimentalmente, è rappresentato da un quadrato che contiene il simbolo dell'elemento ed il numero di nucleoni A. Nella carta, i nuclidi sono disposti in modo che il numero di protoni Z sia indicato in ordinata ed il numero di neutroni N = A-Z in ascissa.

Per la presente versione, l'edizione 1998 della carta dei nuclidi di Karlsruhe è stata comparata con la valutazione NUBASE del 2003 (16) per redigere un elenco dei nuclidi che non erano presenti nella valutazione del 1998. A partire da quest'elenco, abbiamo scelto soltanto i nuclidi che sono stati messi in evidenza sperimentalmente. Sono stati scelti, in particolare, i nuclidi di cui il periodo radioattivo, o la massa, è stata misurata, o anche i nuclidi che sono stati chiaramente identificati. Quando un nuclide è stato identificato, ma il suo periodo radioattivo non è stato misurato, un limite d'individuazione per il periodo radioattivo è dato (superiore o inferiore ad un certo valore). Gli stati metastabili che si disintegrano esclusivamente verso lo stato fondamentale dello stesso nuclide (dunque né con disintegrazione α o β, né con fissione spontanea) non appaiono nella carta soltanto se il tempo del loro periodo radioattivo è superiore a 1s. Quando l'emissione di una particella deriva da uno stato di risonanza di un centro instabile, sono indicate, allo stesso tempo, la larghezza della risonanza ed il periodo radioattivo corrispondente, legate dalla relazione seguente:

$$\Gamma_{c.m.} T_{1/2} \cong \hbar \ln 2, \quad T_{1/2}(s) \cong 4{,}562 \text{ x } 10^{-22} / \Gamma_{c.m.}(\text{MeV})$$

Per le masse situate nell'intervallo A = 266 - 294, abbiamo utilizzato i dati più recenti pubblicati su “Nuclear Data Sheets” (fino al 12 agosto 2005) [17]. Per ciò che riguarda il periodo che non è stato esaminato da NUBASE, cioè del 2003 fino all'estate 2006, le informazioni sui nuclidi sono estratte da “Nuclear Data Sheets” 100 - 107. Inoltre, le pubblicazioni originali sono state esaminate fino all'estate 2006. Un elenco completo dei nuovi nuclidi e degli aggiornamenti effettuati nella presente versione della carta è presentato successivamente sempre in questa scheda.

Le masse atomiche degli elementi e le abbondanze isotopiche sono estratte da J. R. Di Laeter [18]. I dati di disintegrazione non sono indicati per gli isomeri che si disintegrano soltanto con fissione spontanea. Una tabella di periodi radioattivi (inferiori a 0,1 s), di B. Singh [19], è presentata nella scheda. I rendimenti di catena di prodotti di fissione provengono da R. W. Migli [20] e le sezioni efficaci di reazioni neutroniche provengono di N. E. Holden [21].

Explication de la carte des nucléides

Généralités

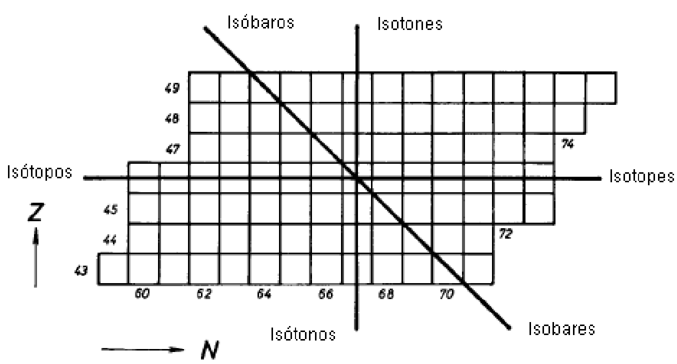
Dans cette carte, chaque nucléide mis en évidence expérimentalement, est représenté par un carré contenant le symbole de l'élément et le nombre de nucléons A. Dans la carte, les nucléides sont disposés de sorte que le nombre de protons Z soit indiqué en ordonnée et le nombre de neutrons N = A-Z en abscisse.

Pour la présente version, l'édition 1998 de la carte des nucléides de Karlsruhe a été comparée à l'évaluation NUBASE de 2003 [16] afin d'établir une liste des nucléides qui n'étaient pas présents dans l'évaluation de 1998. A partir de cette liste, nous avons sélectionné uniquement les nucléides qui ont été mis en évidence expérimentalement. Ont été sélectionnés, en particulier, les nucléides dont la demi-vie, ou bien la masse, a été mesurée, ou encore les nucléides qui ont été clairement identifiés. Lorsqu'un nucléide a été identifié, mais sa demi-vie n'a pas été mesurée, une limite de détection pour la demi-vie est donnée (supérieure ou inférieure à une certaine valeur). Les états métastables se désintégrant exclusivement vers l’état fondamental du même nucléide (donc ni par désintégration α ou β, ni par fission spontanée) ne figurent dans la charte que si leur période de demi-vie est supérieure à 1s. Lorsque l'émission d'une particule résulte d'un état de résonnance d’un noyau instable, sont indiquées, à la fois, la largeur de la résonnance et la demi-vie correspondante, liées par la relation suivante :

$$\Gamma_{c.m.} T_{1/2} \cong \hbar \ln 2, \quad T_{1/2}(s) \cong 4{,}562 \text{ x } 10^{-22} / \Gamma_{c.m.}(\text{MeV})$$

Pour les masses situées dans la plage A = 266 – 294, nous avons utilisé les données les plus récentes publiées dans "Nuclear Data Sheets" (jusqu'au 12 août 2005) [17]. En ce qui concerne la période qui n'a pas été prise en compte par NUBASE, à savoir de 2003 jusqu'à l'été 2006, les informations sur les nucléides sont extraites des "Nuclear Data Sheets" 100 – 107. De plus, les publications originales ont été prises en compte jusqu'à l'été 2006. Une liste complète des nouveaux nucléides et des mises à jour effectuées dans la présente version de la carte est présentée plus loin dans cette brochure.

Les masses atomiques des éléments et les abondances isotopiques sont extraites de J. R. De Laeter [18]. Les données de désintégration ne sont pas indiquées pour les isomères qui ne se désintègrent que par fission spontanée. Un tableau de demi-vies (toutes inférieures à 0,1 s), de B. Singh [19], est présenté dans la brochure. Les rendements de chaîne de produits de fission proviennent de R. W. Mills [20] et les sections efficaces de réactions neutroniques proviennent de N. E. Holden [21].



[16] G. Audi, O. Bersillon, J. Blachot and A.H. Wapstra, The NUBASE evaluation of nuclear and decay properties, Nuclear Physics A, 2003, 729, 3 (2003).
[17] M. Gupta and T. W. Burrows, Nuclear Data Sheets 106, 251 (2005).
[18] J. R. De Laeter, J. K. Bohlke, P. De Bievre, H. Hidaka, H. S. Peiser, K. J. R. Rosman, and P. D. P. Taylor, Atomic Weights of the Elements: Review 2000, Pure & Appl. Chem., 75, 683 (2003).
[19] B. Singh, R. Zywina, and R. Firestone, Table of Superdeformed Nuclear Bands and Fission Isomers, 3rd Edition, Nuclear Data Sheets 97, 241 (2002).
[20] A. Koning, R. Forrest, M. Kellett, R. Mills, H. Henriksson,Y. Rugama “JEFF Report 2.1: The JEFF-3.1 Nuclear Data Library”. OECD/NEA Report to be published. See also R. W. Mills “Fission Product Yield “Evaluation”, Thesis, 1995, The University of Birmingham, UK .
[21] N. E. Holden, Neutron Scattering and Absorption Properties, Handbook of Chemistry and Physics on CD-ROM, version 2006, 11-185, Ed. D.R. Lide, CRC Press, Boca Raton, Florida.

Modi di disintegrazione: colori e simboli

Modes de désintégration : couleurs et symboles

Nuclidi stabili

Nucléide stable

Radionuclidi primordiali, cioè quelli prodotti prima o nel corso della formazione della materia terrestre ed ancora presenti oggi.

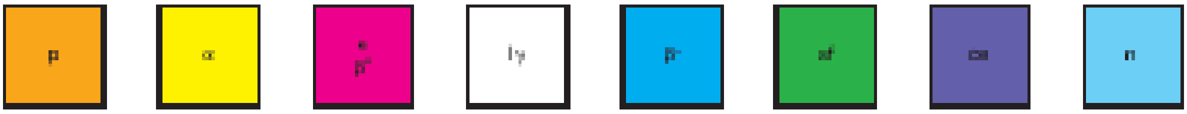
Radionucléides primordiaux, c'est-à-dire ceux produits avant ou au cours de la formation de la matière terrestre et encore présents aujourd'hui.

I modi di disintegrazione sono rappresentati da colori specifici.

Les modes de désintégration sont représentés par des couleurs spécifiques.

p: disintegrazione con emissione di protone
α : disintegrazione alfa
ε : disintegrazione per cattura d'elettrone
β^+ : disintegrazione con emissione di un positrone
Iγ : transizione isomerica
β^- : disintegrazione con emissione di un negatrone
sf: fissione spontanea
ce: emissione d'aggregato es: C 14, 20
n: emissione di neutrone

p : désintégration par émission proton
α : désintégration alpha
ε : désintégration par capture d'électron
β^+ : désintégration par émission d'un positron
Iγ : transition isomérique
β^- : désintégration par émission d'un négatron
sf : fission spontanée
ce : émission d'agrégat ex : C 14, Ne 20
n : émission de neutron



Le indicazioni che appaiono nella parte sinistra riguardano lo stato metastabile e quelle nella parte destra lo stato fondamentale. Iγ indica i fotoni γ prodotti durante la disintegrazione verso lo stato fondamentale dello stesso nuclide (transizione isomerica).

Les indications figurant dans la partie gauche concernent l'état métastable et celles dans la partie droite l'état fondamental. Iγ dénote les photons γ produits pendant la désintégration vers l'état fondamental du même nucléide (transition isomérique).

L'attribuzione delle proprietà di disintegrazione ad uno stato metastabile o allo stato fondamentale è dubbia.

L'attribution des propriétés de désintégration à un état métastable ou à l'état fondamental est incertaine.

Gli stati a vita breve, per i quali solo una disintegrazione con fissione spontanea è stata osservata (isomeri che si disintegrano con fissione spontanea), sono indicati da una barra verticale verde.

Les états à vie courte, pour lesquels seule une désintégration par fission spontanée a été observée (isomères se désintégrant par fission spontanée), sont indiqués par une barre verticale verte.

Emissione di fotoni γ ; sempre indicata con il nuclide padre corrispondente

γ

Emission de photons γ ; toujours indiquée avec le nucléide père correspondant.

Disintegrazione β seguita dall'emissione delle particelle precisate o seguita da fissione spontanea (emissione delle particelle ritardate con disintegrazione β o fissione ritardata con disintegrazione β).

βxp; βxn; βd; βt; βxα; βsf

Désintégration β suivie de l'émission des particules spécifiées ou suivie de fission spontanée (émission des particules retardées par désintégration β ou fission retardée par désintégration β).

Emissione simultanea di due particelle β (« disintegrazione doppio β », es: Te 130 → Xe 130).

$2\beta^-$

Emission simultanée de deux particules β (« désintégration double β », ex : Te 130 → Xe 130).

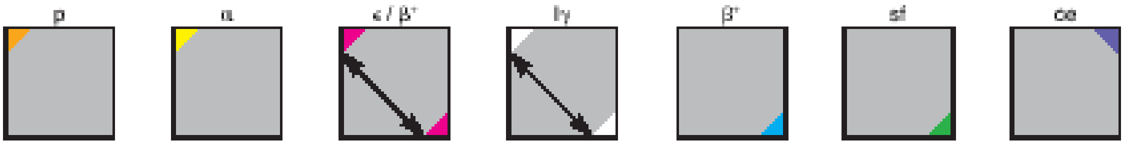
Emissione delle particelle rispettive a partire da un nuclide instabile. Un'emissione simultanea di due particelle è citata soltanto quando l'emissione di una sola particella può essere esclusa per ragioni energetiche (es: Be 6 → 2p)

p; n
2p; 2α

Emission des particules respectives à partir d'un nucléide instable. Une émission simultanée de deux particules n'est mentionnée que lorsque l'émission d'une seule particule peut être exclue pour des raisons énergétiques (ex : Be 6 → 2p).

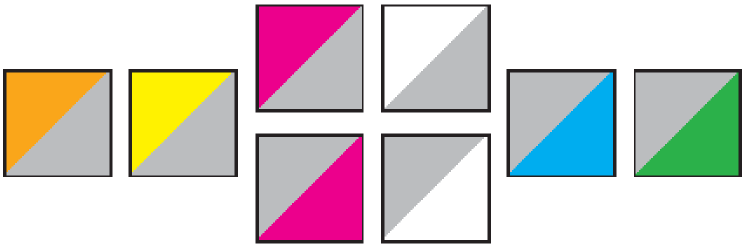
Modi di disintegrazione multipli e relazioni di giunzione
Le relazioni di giunzione dei modi di disintegrazione possono essere indicate da 3 dimensioni diverse dalle superfici colorate e dalla successione dei simboli. I modi di disintegrazione puri sono indicati da un colore unico (vedere la parte precedente). I modi di disintegrazione misti sono indicati dall'utilizzo di triangoli colorati. Un piccolo triangolo colorato, nell'angolo superiore sinistro o nell'angolo inferiore destro, indica una relazione d'allacciamento per questo modo di meno del 5% (viceversa, il modo principale di disintegrazione ha una relazione di giunzione di oltre il 95%), come indicato sulla figura. I piccoli triangoli che rappresentano l'emissione di protone o alfa sono sempre nell'angolo superiore sinistro (primi due quadrati). I triangoli per emissioni β^- e la fissione spontanea sono sempre in fondo a destra. I triangoli che rappresentano ε/β^+ o Iγ possono essere in cima a sinistra o in fondo a destra, secondo il modo principale. Per ε/β^+, il triangolo rosso è in fondo a destra se il modo principale è l'emissione alfa o di protone. Altrimenti, il triangolo rosso è nell'angolo superiore sinistro. Per la transizione isomerica Iγ, un triangolo bianco è in fondo a destra se il modo principale è l'emissione alfa o di protone o ε/β^+, altrimenti, è nell'angolo superiore sinistro. L'emissione d'aggregato è sempre indicata per mezzo di un piccolo triangolo nell'angolo superiore destro. Quindi, i piccoli triangoli sono messi come segue:

Modes de désintégration multiples et rapports d'embranchement
Les rapports d'embranchement des modes de désintégration peuvent être indiqués par 3 tailles différentes des aires colorées ainsi que par la succession des symboles. Les modes de désintégration purs sont indiqués par une couleur unique (voir la partie précédente). Les modes de désintégration mixtes sont indiqués par l'utilisation de triangles de couleur. Un petit triangle de couleur, dans l'angle supérieur gauche ou dans l'angle inférieur droit, indique un rapport de branchement pour ce mode de moins de 5% (inversement, le mode principal de désintégration a un rapport d'embranchement de plus de 95%), tel qu'indiqué sur la figure. Les petits triangles représentant l'émission proton ou alpha sont toujours dans l'angle supérieur gauche (deux premières cases). Les triangles pour les émissions β^- et la fission spontanée sont toujours en bas à droite. Les triangles représentant ε/β^+ ou Iγ peuvent être en haut à gauche ou en bas à droite, selon le mode principal. Pour ε/β^+, le triangle rouge est en bas à droite si le mode majeur est l'émission alpha ou proton. Sinon, le triangle rouge est dans l'angle supérieur gauche. Pour la transition isomérique Iγ, un triangle blanc est en bas à droite si le mode majeur est l'émission alpha ou proton ou ε/β^+, sinon, il est dans l'angle supérieur gauche. L'émission d'agrégat est toujours indiquée à l'aide d'un petit triangle dans l'angle supérieur droit. Ainsi, les petits triangles sont placés comme suit :



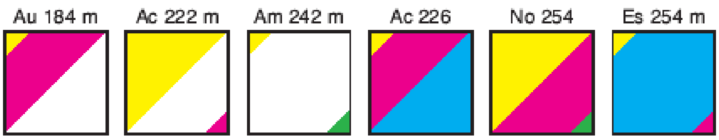
Se la relazione di giunzione del modo principale di disintegrazione è situata nell'intervallo che va da 5 a 50% (che implica una relazione di giunzione per il modo principale situato nell'intervallo dal 50 al 95%), il quadrato è diviso in due secondo una linea diagonale, che collega l'angolo inferiore sinistro all'angolo superiore destro. La posizione dei grandi triangoli segue quanto descritto sopra per i piccoli.

Si le rapport d'embranchement du mode principal de désintégration est situé dans la plage allant de 5 à 50% (impliquant un rapport d'embranchement pour le mode principal situé dans une plage de 50 à 95%), la case est divisée en deux par un lien en diagonale, reliant l'angle inférieur gauche et l'angle supérieur droit. L'emplacement des grands triangles est similaire à ce qui est décrit ci-dessus.



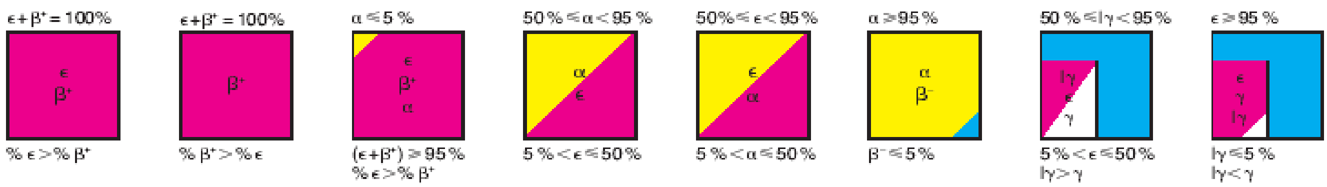
In alcuni casi, sono possibili tre modi di disintegrazione. Alcuni esempi sono indicati sotto.

Dans certains cas, trois modes de désintégration sont possibles. Quelques exemples sont indiqués ci-dessous.



Esempi :

Exemples :

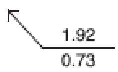
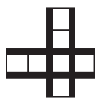


I simboli per i modi di disintegrazione con emissione di particelle sono ordinati secondo la relazione di giunzione con la relazione di giunzione più elevata inizialmente, seguita dai fotoni γ e gli elettroni di conversione. I dati relativi alla transizione isomerica sono indicati secondo la relazione di giunzione del modo di disintegrazione. Le particelle o fissione β ritardate (βn, βp, βsf) precedono o seguono i fotoni γ secondo la loro rispettiva intensità relativa. Per una disintegrazione data, le energie fornite sono classificate in ordine decrescente della loro rispettiva probabilità d'emissione. Nel caso di una disintegrazione β, è utilizzata una norma leggermente differente (vedere sotto).		Les symboles pour les modes de désintégration avec émission de particules sont ordonnés selon le rapport d'embranchement avec le rapport d'embranchement le plus élevé d'abord, suivi par les photons γ et les électrons de conversion. Les données relatives à la transition isomérique sont indiquées selon le rapport d'embranchement du mode de désintégration. Les particules ou fission β retardées (βn, βp, βsf) précèdent ou suivent les photons γ selon leur intensité relative respective. Pour une désintégration donnée, les énergies fournies sont classées par ordre décroissant de leur probabilité d'émission respective. Dans le cas d'une désintégration β, une règle quelque peu différente est utilisée (voir ci-dessous).
I punti indicano altre transizioni dello stesso tipo con intensità più basse.	…	Les points indiquent d'autres transitions du même type avec des intensités plus basses.
Le energie sono espresse in keV per i fotoni γ ed in MeV per le altre particelle. Un simbolo di disintegrazione senza indicazione d'energia significa che la disintegrazione è stata osservata ma che la sua energia non è stata misurata.		Les énergies sont exprimées en keV pour les photons γ et en MeV pour les autres particules. Un symbole de désintégration sans indication d'énergie signifie que la désintégration a été observée mais que son énergie n'a pas été mesurée.
L'energia massima della transizione β è la più frequente. Se esistono altre transizioni con energie superiori, la più elevata energia massima osservata è data in aggiunta come secondo valore.	β^+ 2.7 … β^- 1.2; 1.9…	Energie maximale de la transition β la plus fréquente. Si d'autres transitions avec des énergies supérieures existent, la plus grande énergie maximale observée est donnée en plus comme deuxième valeur.
Transizione β d'energia conosciuta la cui somma delle probabilità di transizione è inferiore a 1%.	β^-… β^+…	Transition β d'énergie connue dont la somme des probabilités de transition est inférieure à 1 %.
La cattura di elettroni è indicata soltanto quando è più probabile della disintegrazione β^+.	ε	La capture d'électrons n'est indiquée que lorsqu'elle est plus probable que la désintégration β^+.
Energie delle particelle in ordine crescente delle relazioni di giunzione. Almeno un valore è indicato anche se la probabilità di transizione più frequente è inferiore a 1%.	α 3.75, 4.43… p 1.56 βp 4.5	Energies des particules dans l'ordre croissant des rapports d'embranchement. Au moins une valeur est indiquée même si la probabilité de transition la plus fréquente est inférieure à 1 %.
Energie dei fotoni γ più frequenti in ordine decrescente delle probabilità d'emissione. Le probabilità inferiori a 1% sono indicate tra parentesi.	γ 815; 1711… γ (1340)	Energies des photons γ les plus fréquents dans l'ordre décroissant des probabilités d'émission. Les probabilités inférieures à 1 % sont indiquées entre parenthèses.
Le energie γ seguite da un asterisco indicano transizioni che seguono un'emissione di nucleoni β- ritardata.	γ 815*	Les énergies γ suivies par un astérisque indiquent des transitions qui suivent une émission de nucléons β-retardée.
Molti fotoni γ a intensità sconosciute si situano nell'intervallo di energie tra 291-1319 keV.	γ 291-1319	Plusieurs photons γ aux intensités inconnues se situant dans l'intervalle d'énergies entre 291-1319 keV.
Gli elettroni di conversione sono segnalati soltanto se sono più probabili dei fotoni γ. Le energie non sono indicate.	e^-	Les électrons de conversion ne sont indiqués que s'ils sont plus probables que les photons γ. Les énergies ne sont pas indiquées.

Sezioni efficaci / **Sections efficaces**

Tutte le sezioni efficaci sono espresse in barn (10^{-24} cm^2) e sono valide per le reazioni con neutroni termici (0.0253 eV).		Toutes les sections efficaces sont exprimées en barn (10^{-24} cm^2) et sont valables pour les réactions avec des neutrons thermiques (0.0253 eV).
Sezione efficace per la reazione (n, γ). Se due valori sono indicati, il primo concerne la formazione del centro del residuale allo stato metastabile, ed il secondo concerne la formazione allo stato fondamentale.	σ	Section efficace pour la réaction (n, γ). Si deux valeurs sont indiquées, la première concerne la formation du noyau du résiduel à l'état métastable, et la deuxième concerne la formation à l'état fondamental.
Sezione efficace di fissione	σ_f	Section efficace de fission
Sezione efficace per il reazione (n, p)	$\sigma_{n,p}$	Section efficace pour la réaction (n, p)
Sezione efficace per il reazione (n, α)	$\sigma_{n,\alpha}$	Section efficace pour la réaction (n, α)
Sezione efficace d'assorbimento	σ_{abs}	Section efficace d'absorption

Altre abbreviazioni e simboli / **Autres abréviations et symboles**

Rendimento di catena (%) di fissione termica di U235 (sopra la linea-freccia) e di Pu239 (al sotto della linea-freccia).		Rendement de chaîne (%) lors de la fission thermique de U235 (au dessus de la ligne fléchée) et de Pu239 (au dessous de la ligne fléchée).
I nuclidi aventi uno strato completo di neutroni o di protoni sono indicati da linee di inquadramento spesse orizzontali o verticali.		Les nucléides ayant une couche complète de neutrons ou de protons sont indiqués par des lignes d'encadrement horizontales ou verticales épaisses.
I simboli "m" e/o "g", segnalano che lo stato metastabile e/o lo stato fondamentale, del nuclide figlio si vede popolato. I simboli sono dati nell'ordine decrescente di probabilità. Le probabilità di disintegrazione inferiori al 5% non sono indicate. Gli indici aggiunti a "m", es: m_1, m_2, sono utilizzati per designare diversi stati metastabili (con m2 essendo uno stato d'energia più elevato di m1).	m; g	Les symboles "m" et/ou "g", indiquent que l'état métastable et/ou l'état fondamental, du nucléide fils se voit peuplé. Les symboles sont donnés dans l'ordre décroissant de probabilité. Les probabilités de désintégration inférieures à 5% ne sont pas indiquées. Les indices ajoutés à "m", ex : m_1, m_2, sont utilisés pour désigner différents états métastables (avec m_2 étant un état d'énergie plus élevée que m_1).

Dati o attribuzioni dubbi.	?	Données ou attributions incertaines.
Nanosecondo, microsecondo, millisecondo, secondo, minuto, ora, giorno, anno.	ns, μs, ms, s, m, h, d, a	Nanoseconde, microseconde, milliseconde, seconde, minute, heure, jour, année.

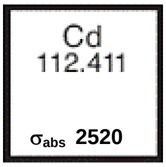
Disposizione dei simboli e dei dati

Disposition des symboles et données

Elementi

Simbolo dell'elemento
Massa atomica standard nel sistema C 12 = 12

Sezione efficace d'assorbimento dei neutroni termici (barn)



Eléments

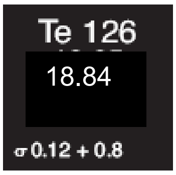
Symbole de l'élément
Masse atomique standard dans le système C 12 = 12

Section efficace d'absorption des neutrons thermiques (barn)

Nuclidi stabili

Simbolo dell'elemento e numero di nucleoni
Tenore isotopico naturale in percentuale atomica

Sezioni efficaci (n, γ) di formazione dello stato metastabile e dello stato fondamentale di Te 127 per i neutroni termici (barn)



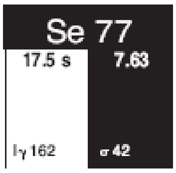
Nucléides stables

Symbole de l'élément et nombre de nucléons
Teneur isotopique naturelle en pourcent atomique

Sections efficaces (n, γ) de formation de l'état métastable et de l'état fondamental de Te 127 pour les neutrons thermiques (barn)

Simbolo dell'elemento e numero di nucleoni

Parte sinistra: periodo radioattivo dello stato metastabile; Energia del fotone γ (keV) emessa in occasione della transizione isomerica
Parte destra: tenore isotopico naturale in percentuale atomica; sezione efficace (n, γ) per i neutroni termici (barn)



Symbole de l'élément et nombre de nucléons

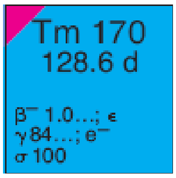
Côté gauche : demi-vie de l'état métastable ;
Energie du photon γ (keV) émis lors de la transition isomérique

Côté droit : teneur isotopique naturelle en pourcent atomique; section efficace (n, γ) pour les neutrons thermiques (barn)

Nuclidi instabili

Simbolo dell'elemento e numero di nucleoni
Periodo radioattivo

Modi di disintegrazione ed energia massima di irradiazione b^- (MeV)
Energia γ (keV), elettroni di conversione,
Sezione efficace (n, γ) (barn)



Nucléides instables

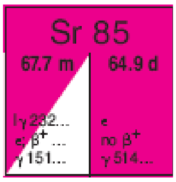
Symbole de l'élément et nombre de nucléons
Demi-vie

Modes de désintégration et énergie maximale du rayonnement β^- (MeV)
Energie γ (keV), électrons de conversion,
Section efficace (n, γ) (barn)

Simbolo dell'elemento e numero di nucleoni

Periodi radioattivi

I due stati si disintegrano per cattura di elettroni; lo stato metastabile si disintegra verso lo stato fondamentale con una relazione di giunzione per Iγ situats nell'intervallo che va dal 50% al 95%



Symbole de l'élément et nombre de nucléons

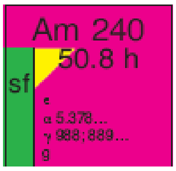
Demi-vies

Les deux états se désintègrent par capture d'électrons ; l'état métastable se désintègre vers l'état fondamental avec un rapport d'embranchement pour Iγ situé dans la plage allant de 50 % à 95 %

Simbolo dell'elemento e numero di nucleoni

Parte sinistra: isomero che si disintegra con fissione spontanea, T < 0,1 s

Parte destra: dati di disintegrazione dello stato fondamentale. "g" segnala che il discendente Pu 240g si forma almeno al 95%; lo stato metastabile Pu 240m può essere presente in proporzioni che possono raggiungere il 5%

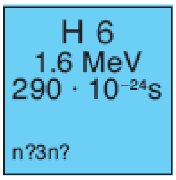


Symbole de l'élément et nombre de nucléons

Côté gauche : isomère se désintégrant par fission spontanée, T < 0,1 s

Côté droit : données de désintégration de l'état fondamental. "g" indique que le descendant Pu 240g se forme au moins à 95 %; l'état métastable Pu 240m peut être présent dans des proportions pouvant atteindre 5 %

Quando l'emissione di una particella deriva da uno stato di risonanza in un centro instabile, la larghezza di risonanza Γ (MeV) e il periodo radioattivo $T_{1/2}$ sono indicati



Lorsque l'émission d'une particule résulte d'un état de résonnance dans un noyau instable, la largeur de résonnance Γ (MeV) ainsi que la demi-vie $T_{1/2}$ sont indiquées

Explanation of the Chart of the Nuclides

General

In this chart each experimentally observed nuclide is represented by a square containing the symbol of the element and the number of nucleons A. In the chart the nuclides are arranged such that the proton number Z is given on the ordinate and the neutron number N = A– Z on the abscissa.

In the present nuclide chart update, the 1998 edition of the Karlsruhe Nuclide Chart was compared to the NUBASE 2003 evaluation [16] to establish a list of nuclides which were not present in the 1998 evaluation. From this list we have selected only nuclides which have been measured experimentally. In particular, nuclides were selected where the half-life or the mass has been determined or the nuclide has been clearly identified. Where a nuclide has been identified but the half-life has not been measured, a detection limit for half-life is given (greater or lower than a value).

Metastable states, which do not undergo α-, or β-decay, or spontaneous fission, i.e. decay only by gamma emission, are included only if their half-life is larger than 1 s. Where emission of a particle results from a resonance state in unstable nuclides, both the resonance width and corresponding half-life are given using the relations:

$$\Gamma_{c.m.} T_{1/2} \cong \hbar \ln 2,\quad T_{1/2}(s) \cong 4.562 \times 10^{-22} / \Gamma_{c.m.}(MeV)$$

For mass numbers in the range A = 266 – 294 we have used the latest 2005 (till August 12, 2005) Nuclear Data Sheets revision [17]. For the period not covered by NUBASE, i.e. 2003 until summer 2006, nuclide information has been taken from Nuclear Data Sheets 100 – 107. In addition, original publications up to summer 2006 were taken into account. A full list of new and updated nuclides in the present chart is given later in this brochure.

Atomic weights of the elements and isotopic abundances have been taken from J. R. De Laeter [18]. For isomers which decay exclusively by spontaneous fission, no decay data is given in the chart. A table of half-lives (all less than 0.1 s), from B. Singh [19], are given in the brochure. Chain yields are from R. W. Mills [20] and neutron cross sections are from N. E. Holden [21].

「核種チャート」の解説

概要

本核種チャートでは、実験的に観察された核種を、元素記号および核子数:Aを含む区画によりで表す。各核種の陽子数:Zは縦軸に、中性子数: N (= A– Z) は横軸に対応する。

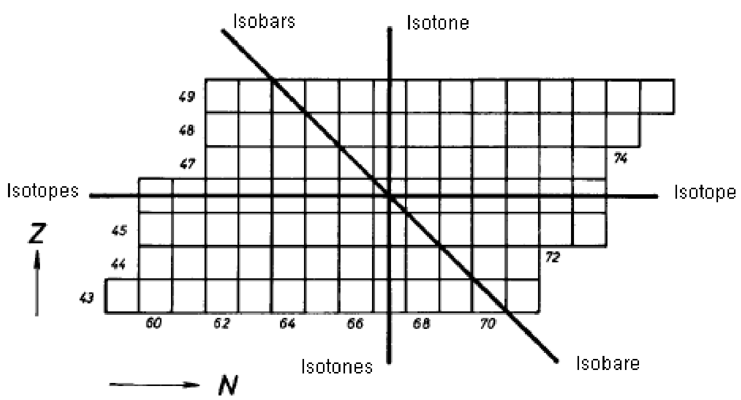
本チャートでは、「カールスルーエ核種チャート1998年版」と「NUBASE 2003年評価版 [16]」とを比較し、前者に記載されていなかった核種をリストアップし、この中から実験的に観察された核種のみ、特に、半減期あるいは質量が決定されたもの、あるいは核種が明確に特定できたもの、を選んで掲載している。核種が特定できても半減期が測定されていないものについては、半減期の測定限界値（ある値以上、あるいは以下）を記している。

α崩壊、β崩壊、あるいは自発核分裂のいずれも行わずγ放出のみを行う準安定状態については、本γ放出の半減期が1秒よりも長い場合についてのみ掲載する。共鳴状態の不安定核種から粒子が放出される場合、共鳴幅と半減期の関係は以下の式で示される。

$$\Gamma_{c.m.} T_{1/2} \cong \hbar \ln 2,\quad T_{1/2}(s) \cong 4.562 \times 10^{-22} / \Gamma_{c.m.}(MeV)$$

質量数:Aが266～294の核種に関しては、「Nuclear Data Sheetsの最新版（2005年版、2005年8月12日までのデータを掲載）[17]」を引用している。2003年以降2006夏までの、NUBASEで掲載されていない期間に関しては、「Nuclear Data Sheets 100 – 107」の核データを引用している。更に、2006年夏までに掲載された論文のデータも考慮している。本チャートにて新たに加えられた、あるいは改定された核種のリストは本冊子で後述する。

各元素の原子量および同位体存在比はJ. R. De Laeterの文献 [18] を引用している。自発核分裂のみで崩壊する異性核の崩壊データは、本チャートには記載していない。その他、B. Singhの文献 [19] 記載の0.1秒以下の半減期表、R. W. Millsの文献 [20] 記載の連鎖収率、N. E. Holdenの文献 [21] 記載の中性子断面積を本冊子に掲載している。



[16] G. Audi, O. Bersillon, J. Blachot and A.H. Wapstra, The NUBASE evaluation of nuclear and decay properties, Nuclear Physics A, 2003, 729, 3 (2003).
[17] M. Gupta and T. W. Burrows, Nuclear Data Sheets 106, 251 (2005).
[18] J. R. De Laeter, J. K. Bohlke, P. De Bievre, H. Hidaka, H. S. Peiser, K. J. R. Rosman, and P. D. P. Taylor, Atomic Weights of the Elements: Review 2000, Pure & Appl. Chem., 75, 683 (2003).
[19] B. Singh, R. Zywina, and R. Firestone, Table of Superdeformed Nuclear Bands and Fission Isomers, 3rd Edition, Nuclear Data Sheets 97, 241 (2002).
[20] A. Koning, R. Forrest, M. Kellett, R. Mills, H. Henriksson,Y. Rugama "JEFF Report 2.1: The JEFF-3.1 Nuclear Data Library". OECD/NEA Report to be published. See also R. W. Mills "Fission Product Yield "Evaluation", Thesis, 1995, The University of Birmingham, UK .
[21] N. E. Holden, Neutron Scattering and Absorption Properties, Handbook of Chemistry and Physics on CD-ROM, version 2006, 11-185, Ed. D.R. Lide, CRC Press, Boca Raton, Florida.

Decay Modes: Colour and Symbols

崩壊の種類:色と記号

Stable nuclide

安定核種

Primordial radionuclides, i.e. those formed in the build-up of terrestrial matter and still present today.

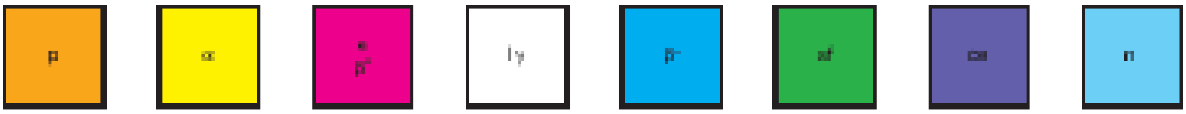
原生核種、即ち、地球創生時より現在まで存在する核種

Decay modes are represented by specific colours.

p: Proton decay
α: Alpha decay
ε: Electron capture
β^+: Positron decay
Iγ: Isomeric transition
β^-: Negatron decay
sf: Spontaneous fission
ce: Cluster emission e. g. C 14, Ne 20
n: Neutron emission

崩壊様式は以下のように色分けする。

p: 陽子崩壊（オレンジ色）
α: α崩壊（黄色）
ε: 電子捕獲（ピンク）
β^+: β^+崩壊（ピンク）
Iγ:: 異性核転移（白）
β^-: β^-崩壊（青）
sf: 自発核分裂（緑）
ce: クラスター放出（例　C 14, Ne 20、紫）
n: 中性子放出（水色）



The data given in the left part apply to the metastable state, those in the right part to the ground state. Iγ denotes γ-quanta due to the decay to the ground state of the same nuclide (isomeric decay).

左側は準安定状態、右側は基底状態を示す。Iγ
は同一核種の基底状態への崩壊（異性核崩壊）に伴うγ放出を示す。

The assignment of decay properties to the metastable or ground state is uncertain.

⟷

準安定状態か基底状態かが不明確な崩壊を示す。

One or more short-lived states, for which only decay via spontaneous fission has been observed (spontaneously fissioning isomers) are indicated by a vertical green bar.

自発核分裂による崩壊のみが観察されている場合（自発核分裂異性核）、1つあるいはそれ以上の短寿命状態を緑色の縦棒で示す。

Emission of γ-quanta; they are always listed together with the respective parent nuclide.

γ

γ放出。常に親核種と共に示す。

Emission of the specified particles or spontaneous fission from an excited level of the daughter nuclide, populated via β-decay ("β-delayed particle emission or fission").

βxp; βxn; βd; βt; βxα; βsf

β崩壊で生じた励起状態の娘核種から特定粒子が放出される、あるいは本娘核種が自発核分裂をするもの（β遅延粒子放出あるいはβ遅延核分裂）。

Simultaneous emission of two β-particles ("double β-decay", e.g. Te 130 → Xe 130).

$2\beta^-$

同時に2回のβ崩壊をするもの
（2重β崩壊、例えば Te 130 → Xe 130）。

Emission of the specified particles from a particle-unstable nuclide. Simultaneous emission of two particles is indicated only, if one-particle-emission is excluded for energetical reasons (e.g. Be 6 → 2p).

p; n
2p; 2α

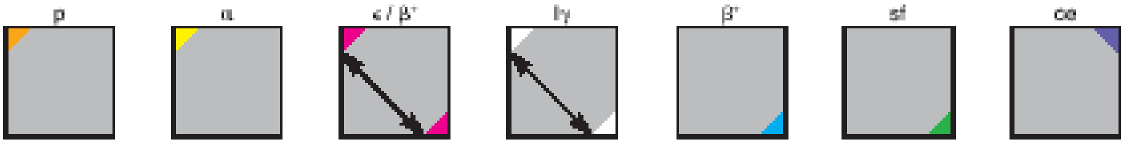
粒子不安定な核種から特定粒子が放出されるもの。エネルギー的理由により1粒子放出があり得ない場合にのみ、2粒子の同時放出を記載する
（例えば Be 6 → 2p).

Multiple Decay Modes and Branching Ratios

The branching ratios of the decay modes are indicated by 3 different sizes of the coloured sections and by the sequence of the symbols. Pure decay modes are indicated by a single colour (e.g. see previous section). Mixed decay modes are indicated by the use of coloured triangles. A small coloured triangle in the top left or bottom right indicates a branching ratio for this mode of ≤ 5% (conversely, the major mode has a branching ratio of ≥ 95%) as shown in the figure. The small triangles representing proton or alpha emission are always on the top left corner (first two boxes). The triangles for β^- emission or spontaneous fission are always at the bottom right. Triangles representing ε/β^+ or Iγ may be at the top left or bottom right depending on the major mode. For ε/β^+, the red triangle is at the bottom right if the main mode is alpha or proton emission.
Otherwise, the red triangle is at the top left corner. For isomer transition Iγ, the white triangle is at the bottom right if the main mode is α- or p- emission or ε/β^+, otherwise it is at the top left corner. Cluster emission is always indicated with a small triangle in the top right corner. Hence the location of the small triangles is as follows:

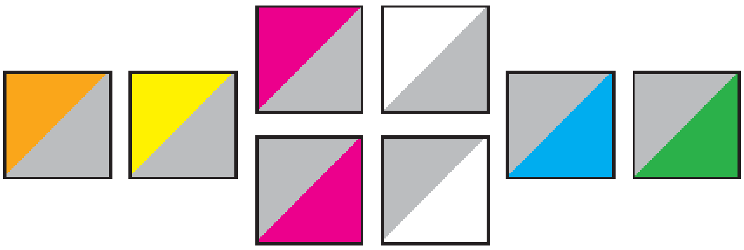
複合崩壊および分岐率

複数崩壊の分岐率は、区画内で色分けされた部分の形状および3種の大きさの違い、およびその配列により表す。単一崩壊では区画全体を単一色で現すのに対し（前節参照）、複合崩壊は区画内に別の色の三角形で表す。左上あるいは右下に小さな三角形がある場合には、分岐率が5%以下、即ち、主な崩壊様式の割合が95%以上であることを示す。陽子あるいはα粒子を放出する崩壊は、下記の左側2図のように区画内左上の三角形で表す。β^-崩壊や自発核分裂は右下の三角形で表す。電子捕獲/β^+崩壊あるいは異性核転移では、主な崩壊様式に応じて区画内の左上あるいは右下の三角形で表す。この場合、主な崩壊様式がα粒子放出あるいは陽子放出であれば、電子捕獲/β^+崩壊を右下の赤い三角形でし、それ以外では左上の赤い三角形で表す。異性核転移: Iγは主な崩壊様式がα粒子放出、陽子放出、あるいは電子捕獲/β^+崩壊の場合には右下の白い三角形で表し、それ以外の場合には左上の白い三角形で表す。クラスター放出の場合は常に右上の三角形で表す。
以下に凡例を示す。



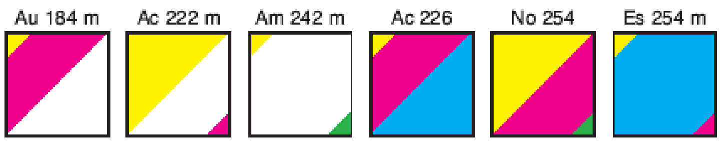
If the branching ratio of the minor mode is in the range 5 – 50% (implying a branching ratio for the major mode in the range 50 – 95%), the box is divided into two by a diagonal connection the lower left and top right corners. The location of the large triangles is similar to that described above.

分岐率が5～50%、即ち主な崩壊様式の割合が50～95%の場合、区画は斜線により左上と右下に2等分される。この際の三角形の位置は上述同様である。



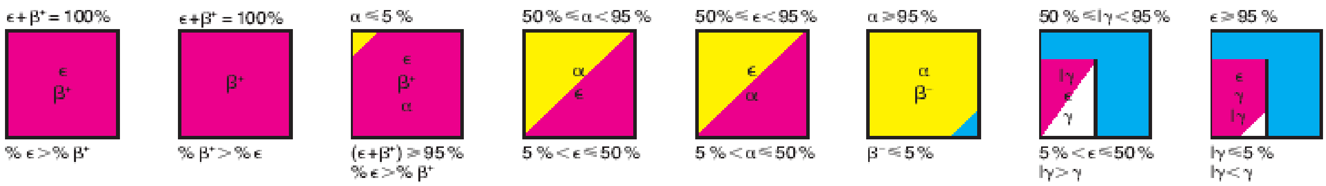
In some cases, three decay modes are possible. Some examples are shown below.

3つの崩壊様式が存在する場合の例を以下に示す。

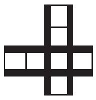


Examples:

例



The symbols for the particle emitting decay modes are arranged according to branching ratio with the highest branching ratio first, followed by γ-quanta and conversion electrons. The data for the isomeric decay have been arranged corresponding to the branching ratio of the decay mode. β-delayed particles or fission (βn, βp, βsf) precede or follow the γ-quanta according to the relative intensities. For a given type of radiation the sequence of the energies corresponds to the relative intensities (in decreasing order) of the respective radiation. In case of β-decay a slightly different rule is used (see below).		粒子放出を伴う崩壊では、分岐率の大きい順で記号を記す。続いてγ放出と転換電子を記す。異性核転移では分岐率の順に記す。β遅延粒子放出やβ遅延自発核分裂(βn, βp, βsf)は、相対強度に応じてγ放出の前後に記す。 それぞれの放射様式では、エネルギーは相対強度の大きい順に記す。但し、β遅延崩壊の場合は、以下に示すようにやや異なる規則を用いる。
Points indicate further transitions of the same type with lower intensities.	…	・・・は、同様式で低い強度の転移が更にあることを示す。
<u>Energies</u> are given in keV for γ-quanta, in MeV for all kinds of particles. A radiation symbol without energy value indicates that the radiation occurs but the energy has not been measured.		放射エネルギーは、γ放出の場合はkeV単位で、全ての粒子放出の場合にはMeV単位で示す。エネルギーの値が記載されていない場合は、放射自体は生ずるものの放射エネルギーがまだ測定されていないことを示す。
Endpoint energy of the most abundant β-transition. In case further transitions with higher energies exist, the second number corresponds to the hightest endpoint energy observed.	β^+ 2.7 … β^- 1.2; 1.9…	最も分岐収率の大きなβ転移の最終エネルギー。更にエネルギーの大きな転移がある場合には、2番目の数値が測定されている最大の最終エネルギーを示す。
β-transitions with known energies, for which the sum of their abundances is less than 1%.	β^- … β^+…	合計収率が1%未満で、エネルギーが判明しているβ転移。
Electron capture is specified only, if it is more probable than β^+-decay.	ε	電子捕獲は、β^+崩壊よりも収率が大きい場合のみ記載。
Particle energies listed according to decreasing probabilities of the respective transitions. At least one energy is given, even if the abundance of the most prominent group is less than 1%.	α 3.75, 4.43… p 1.56 βp 4.5	粒子のエネルギーは、転移収率が大きい順に記載。最も顕著なグループの収率が1%未満の場合でも最低1つのエネルギー値は記載。
Energies of the strongest γ-quanta arranged in order of decreasing intensities. Intensities less than 1% are given in brackets.	γ 815; 1711… γ (1340)	エネルギーが最も大きなγ放出については強度が大きい順に記載。強度が1%未満の場合は( )内に記載。
γ-Energies followed by an asterisk denote transitions after β-delayed particle emission.	γ 815*	γエネルギーに * が付くものは、β遅延粒子放出後の転移を示す。
Several γ-quanta of unknown intensities within the energy interval 291-1319 keV.	γ 291-1319	291～1319keVのエネルギー範囲内にいくつかの強度不明なγ放出があることを示す。
Conversion electrons are specified only if they are more abundant than the γ-quanta. Energies are not quoted.	e^-	転換電子はγ放出よりも収率が高い場合についてのみ記載。エネルギーは記載せず。
Cross Sections All cross sections are given in barn (10^{-24} cm^2) and refer to reactions with thermal neutrons (0.0253 eV).		**断面積** 断面積は全て0.0253eVの熱中性子に対する値で、バーン(10^{-24} cm^2)単位で示す。
Cross section for the (n, γ) reaction. If two values are given, the first refers to the formation of the product nucleus in the metastable, the second to the formation in the ground state.	σ	(n, γ) 反応に対する断面積。2つの値が記載されている場合には、1番目の値が準安定状態の核種生成反応、2番目が基底状態の核種の生成反応に相当する。
Fission cross section	σ_f	核分裂断面積
(n, p) cross section	$\sigma_{n,p}$	(n, p) 反応の断面積
(n, α) cross section	$\sigma_{n,\alpha}$	(n, α) 反応の断面積
Absorption cross section	σ_{abs}	吸収断面積
Additional Symbols and Abbreviations Chain yield (%) for the thermal neutron fission of U235 (above) and Pu239 (below) the arrowed line.	↖ 1.92 0.73	**その他の記号および略号** U235の熱中性子核分裂に対する連鎖収率(%)を矢印の上に、Pu239の熱中性子核分裂に対する連鎖収率(%)を矢印の下に記載。

Nuclides with a closed neutron or proton shell are characterized by heavy horizontal or vertical lines.		中性子閉殻あるいは陽子閉殻を有する核種は太線で強調する。
The symbols “m” and/or “g” indicate that the metastable and/or ground state of the daughter nuclide is populated, respectively. The symbols are presented in order of decreasing probability. Branches with probabilities less than 5% are not shown. Subscripts on “m”, e.g. m_1, m_2, are used to denote different metastable states (with m_2 being a higher energy state than m_1).	m; g	“m” と “g” れぞれ娘核種が準安定状態あるいは基底状態で生成されることを示し、収率の高い順に記載。但し、収率が5%未満の分岐は記載しない。“m_1”, “m_2” のような “m” の添え字は異なる準安定状態を示し、“m_2” は “m_1” よりも高いエネルギー準位にあることを意味する。
Data or assignment uncertain.	?	データあるいは指摘が不明確
Nanosecond, microsecond, millisecond, second, minute, hour, day, year.	ns, μs, ms, s, m, h, d, a	ナノ秒、マイクロ秒、ミリ秒、秒、分、時間、日、年

Arrangement of Symbols and Data

記号およびデータの配置

Elements

symbol of the element
standard atomic weight based on C 12 = 12

absorption cross section for thermal neutrons (barn)

元素

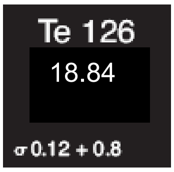
元素記号
C12 = 12 とする原子量

熱中性子に対する吸収断面積（バーン）

Stable Nuclides

symbol of the element, number of nucleons
abundance in naturally occuring element (atom %)

(n, γ)-cross sections for the formation of the metastable and the ground state of Te 127 by thermal neutrons (barn)



安定核種

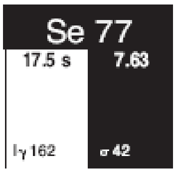
元素記号、核子数
天然存在元素中の本核種の存在割合(at%)

熱中性子により準安定状態および基底状態のTe 127を生成する (n, γ) 反応の断面積（バーン）

symbol of the element, number of nucleons

left hand side: half-life of metastable state; γ-energy (keV) of the isomeric transition

right hand side: abundance in the natural element (atom %)
(n, γ)-cross sections for the thermal neutrons (barn)



元素記号、核子数

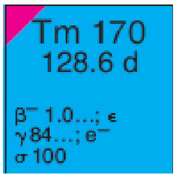
左側：準安定状態の半減期、異性核転移に伴うγエネルギー（keV）

右側：自然存在元素中の本核種の存在割合(at%)、熱中性子に対する (n, γ) 反応の断面積（バーン）

Unstable Nuclides

symbol of the element, number of nucleons
half-life

modes of decay, endpoint energy of β⁻-radiation (MeV)
γ-energy (keV), conversion electrons,
(n, γ)-cross section (barn)



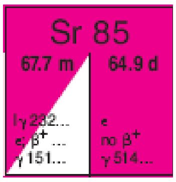
不安定核種

元素記号、核子数
半減期

崩壊様式、β⁻放射の最終エネルギー（MeV）
γエネルギー（keV）、転換電子
(n, γ) 反応の断面積（バーン）

symbol of the element, number of nucleons
half-lives

both states decay by electron capture; the metastable state decays to the ground state with a branching ratio for Iγ in the range of 50% – 95%



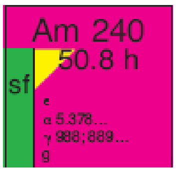
元素記号、核子数
半減期

左右両者とも電子捕獲により崩壊し、Iγ崩壊への分岐率は50～95%の範囲内で準安定状態から基底状態への崩壊を行う。

symbol of the element, number of nucleons

left hand side: spontaneous fission isomer, T < 0.1 s

right hand side: decay data of the ground state
"g" indicates that the daughter Pu 240g is formed to at least 95 %; a population of Pu 240m up to 5% cannot be excluded

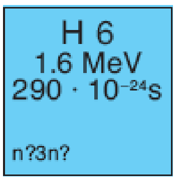


元素記号、核子数

左側:半減期0.1秒未満の自発核分裂

右側:基底状態の崩壊データ
"g" は娘核種の収率としてPu 240gは95%以上、Pu 240mは5%以下であることを示す。

where emission of a particle results from a resonance state in an unstable nucleus, both the resonance width Γ (MeV) and the half-life $T_{1/2}$ are given



共鳴状態の不安定核種から粒子放出がなされる場合には、共鳴幅 Γ(MeV) と半減期$T_{1/2}$ の双方を記載する。

Explanation of the Chart of the Nuclides

General

In this chart each experimentally observed nuclide is represented by a square containing the symbol of the element and the number of nucleons A. In the chart the nuclides are arranged such that the proton number Z is given on the ordinate and the neutron number N = A– Z on the abscissa.

In the present nuclide chart update, the 1998 edition of the Karlsruhe Nuclide Chart was compared to the NUBASE 2003 evaluation [16] to establish a list of nuclides which were not present in the 1998 evaluation. From this list we have selected only nuclides which have been measured experimentally. In particular, nuclides were selected where the half-life or the mass has been determined or the nuclide has been clearly identified. Where a nuclide has been identified but the half-life has not been measured, a detection limit for half-life is given (greater or lower than a value).
Metastable states, which do not undergo α-, or β-decay, or spontaneous fission, i.e. decay only by gamma emission, are included only if their half-life is larger than 1 s. Where emission of a particle results from a resonance state in unstable nuclides, both the resonance width and corresponding half-life are given using the relations:

$$\Gamma_{c.m.} T_{1/2} \cong \hbar \ln 2, \quad T_{1/2}(s) \cong 4.562 \times 10^{-22} / \Gamma_{c.m.}(MeV)$$

For mass numbers in the range A = 266 – 294 we have used the latest 2005 (till August 12, 2005) Nuclear Data Sheets revision [17]. For the period not covered by NUBASE, i.e. 2003 until summer 2006, nuclide information has been taken from Nuclear Data Sheets 100 – 107. In addition, original publications up to summer 2006 were taken into account. A full list of new and updated nuclides in the present chart is given later in this brochure.

Atomic weights of the elements and isotopic abundances have been taken from J. R. De Laeter [18]. For isomers which decay exclusively by spontaneous fission, no decay data is given in the chart. A table of half-lives (all less than 0.1 s), from B. Singh [19], are given in the brochure**. Chain yields** are from R. W. Mills [20] and neutron cross sections are from N. E. Holden [21].

핵종(核種) 도표 설명

일반적 사항

실험적으로 관찰된 각 핵종은 이 도표에서 원소기호 및 핵자 A.의 수를 포함하는 사각형으로 대표된다. 도표에서 핵종의 양성자 수 Z는 종축에, 중성자 수 N = A-Z는 횡축에 표시된다.

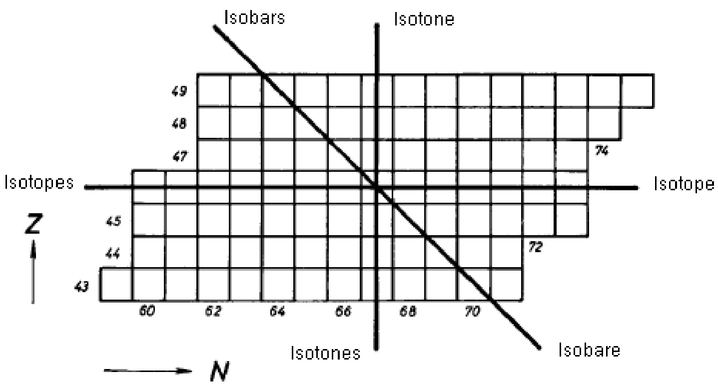
최근 갱신된 핵종 도표에서서는 1998년 판 Karlsruhe 핵종 도표가 NUBASE 2003년 평가와 [16] 비교되었는데, 이는 1998년 평가에서는 존재하지 않았던 핵종의 리스트를 만들기 위함이다. 이 리스트로부터 우리는 실험적으로 측정된 핵종만 선정했다. 특히, 반감기 또는 질량이 결정되는 지점, 또는 핵종이 명확하게 확인되는 지점에서 핵종을 선정했다. 핵종이 확인되었으나 반감기가 측정되지 않은 곳에는, 반감기 탐지 한계점을 표시했다.(값보다 크거나 작게).

α-붕괴나 β-붕괴를 겪지 않은 준 안정 상태, 또는 자발핵분열(즉 감마선 방출에 의한 붕괴)은 반감기가 1 s. 보다 더 커야만 포함되었다. 불안정한 핵종 속의 공명 상태로 인해 입자가 방출되는 경우, 공명 폭 및 해당 반감기 모두는 다음의 관계식을 이용하여 계산한다:

$$\Gamma_{c.m.} T_{1/2} \cong \hbar \ln 2, \quad T_{1/2}(s) \cong 4.562 \times 10^{-22} / \Gamma_{c.m.}(MeV)$$

A = 266 - 294 범위 내에 있는 질량수를 얻기 위해 우리는 2005년 (2005년8월 12일 까지) Nuclear Data Sheets 최신개정판 [17]을 사용했다. NUBASE가 다루지 못한 기간, 즉2003년부터 2006년 여름까지의 핵종 정보는 Nuclear Data Sheets 100 - 107에서 따왔다. 여기에 2006년 여름까지 NUBASE의 간행물도 고려하였다. 현 도표에 제시된 새로 개정된 전체 핵종 리스트는 이 브로슈어의 뒤편에도 나온다.

원소들의 원자량 및 동위원소 존재도는 J. R. De Laeter [18]로부터 가져왔다. 도표에는 오직 자발핵분열에 의해서만 붕괴하는 이성체에 대한 붕괴 데이터가 없다. B. Singh [19] 로부터 반감기 (전부 0.1s. 이하) 표를 사용했다. 연쇄반응률은 R. W. Mills[20] 에서, 중성자 단면은 N. E. Holden [21].에서 가져왔다.



[16] G. Audi, O. Bersillon, J. Blachot and A.H. Wapstra, The NUBASE evaluation of nuclear and decay properties, Nuclear Physics A, 2003, 729, 3 (2003).
[17] M. Gupta and T. W. Burrows, Nuclear Data Sheets 106, 251 (2005).
[18] J. R. De Laeter, J. K. Bohlke, P. De Bievre, H. Hidaka, H. S. Peiser, K. J. R. Rosman, and P. D. P. Taylor, Atomic Weights of the Elements: Review 2000, Pure & Appl. Chem., 75, 683 (2003).
[19] B. Singh, R. Zywina, and R. Firestone, Table of Superdeformed Nuclear Bands and Fission Isomers, 3rd Edition, Nuclear Data Sheets 97, 241 (2002).
[20] A. Koning, R. Forrest, M. Kellett, R. Mills, H. Henriksson,Y. Rugama "JEFF Report 2.1: The JEFF-3.1 Nuclear Data Library". OECD/NEA Report to be published. See also R. W. Mills "Fission Product Yield "Evaluation", Thesis, 1995, The University of Birmingham, UK .
[21] N. E. Holden, Neutron Scattering and Absorption Properties, Handbook of Chemistry and Physics on CD-ROM, version 2006, 11-185, Ed. D.R. Lide, CRC Press, Boca Raton, Florida.

Decay Modes: Colour and Symbols

붕괴 방식: 색깔과 기호

Stable nuclide

안정된 핵종

Primordial radionuclides, i.e. those formed in the build-up of terrestrial matter and still present today.

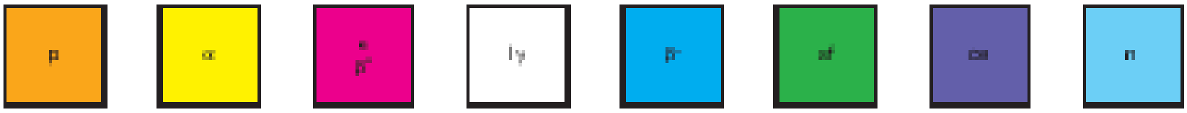
원시 방사성 핵종, 즉 지구 물질 형성 시에 만들어져서 오늘날까지 존재하는 것들.

Decay modes are represented by specific colours.

p: Proton decay
α: Alpha decay
ε: Electron capture
β^+: Positron decay
Iγ: Isomeric transition
β^-: Negatron decay
sf: Spontaneous fission
ce: Cluster emission e. g. C 14, Ne 20
n: Neutron emission

붕괴 방식은 특정한 색깔에 의해 대표된다.

p: 양자 붕괴
α: 알파 붕괴
ε: 전자 포획
β^+: 양전자 감퇴
Iγ: 이성체 전이
β^-: 음전자 감퇴
sf: 자발핵 분열
ce: 클러스터 방출 (예를 들어 C 14, Ne 20의 경우)
n: 중성자 방출



The data given in the left part apply to the metastable state, those in the right part to the ground state. Iγ denotes γ-quanta due to the decay to the ground state of the same nuclide (isomeric decay).

왼쪽 부분에 보이는 데이터는 준안정 상태에 해당되며, 오른쪽 부분의 데이터는 기저 상태에 해당된다. Iγ이란 동일한 핵종이 기저상태로 붕괴함으로 인한(이성체 감퇴) γ-양자들을 표시한다.

The assignment of decay properties to the metastable or ground state is uncertain.

⟷

준안정 또는 기저 상태로의 붕괴 정도를 지정하는 것은 불확실하다.

One or more short-lived states, for which only decay via spontaneous fission has been observed (spontaneously fissioning isomers) are indicated by a vertical green bar.

한 개 혹은 그 이상의 짧은 반감기 준위들. 자발핵분열을 통한 유일한 붕괴로 관찰되었는데 (자발핵분열된 이성체), 이는 수직의 녹색 막대기로 표시된다.

Emission of γ-quanta; they are always listed together with the respective parent nuclide.

γ

γ-양자 방출; 항상 각각의 모 핵종과 함께 열거된다.

Emission of the specified particles or spontaneous fission from an excited level of the daughter nuclide, populated via β-decay ("β-delayed particle emission or fission").

βxp; βxn; βd; βt; βxα; βsf

β-붕괴(β-지연 입자 방출 또는 분열)를 통한 특정 입자의 방출, 또는 딸 핵종의 들뜬 준위로부터의 자발핵분열.

Simultaneous emission of two β-particles ("double β-decay", e.g. Te 130 → Xe 130).

$2\beta^-$

두 β-입자의 동시 방출 ("두 배의 β-붕괴", 예를 들면 Te 130 → Xe 130).

Emission of the specified particles from a particle-unstable nuclide. Simultaneous emission of two particles is indicated only, if one-particle-emission is excluded for energetical reasons (e.g. Be 6 → 2p).

p; n
2p; 2α

입자-불안정 핵종으로부터 특정 입자의 방출. 단 입자 방출이 에너지적인 이유 때문에 배제되는 경우에만 두 개 입자의 동시 방출이 제시된다. (예를 들면 Be 6 → 2p).

Multiple Decay Modes and Branching Ratios

다수 붕괴 방식 및 분기 비율

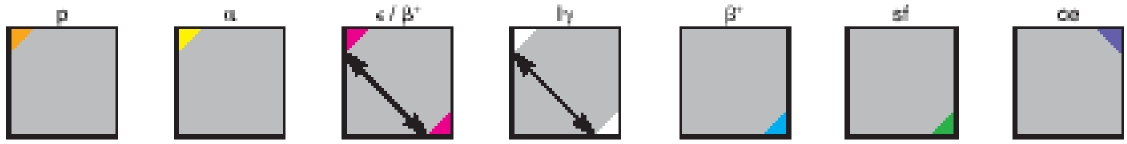
The branching ratios of the decay modes are indicated by 3 different sizes of the coloured sections and by the sequence of the symbols. Pure decay modes are indicated

붕괴 방식의 분기 비율은 3개의 다른 크기의 색단면과 기호의

by a single colour (e.g. see previous section). Mixed decay modes are indicated by the use of coloured triangles. A small coloured triangle in the top left or bottom right indicates a branching ratio for this mode of ≤ 5% (conversely, the major mode has a branching ratio of ≥ 95%) as shown in the figure. The small triangles representing proton or alpha emission are always on the top left corner (first two boxes). The triangles for β^- emission or spontaneous fission are always at the bottom right. Triangles representing ε/β^+ or Iγ may be at the top left or bottom right depending on the major mode. For ε/β^+, the red triangle is at the bottom right if the main mode is alpha or proton emission.
Otherwise, the red triangle is at the top left corner. For isomer transition Iγ, the white triangle is at the bottom right if the main mode is α- or p- emission or ε/β^+, otherwise it is at the top left corner. Cluster emission is always indicated with a small triangle in the top right corner. Hence the location of the small triangles is as follows:

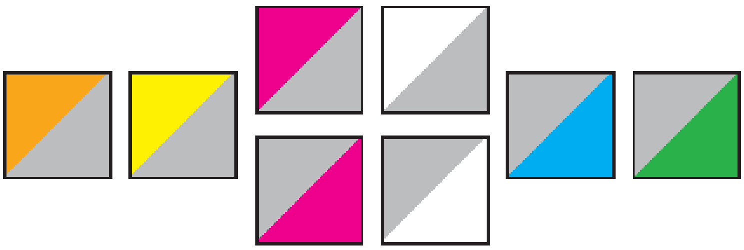
순서로 표시된다. 순수 붕괴 방식은 단색으로 나타난다 (예를 들어 이전 섹션을 보라). 혼합 붕괴 방식은 색깔 있는 삼각형을 사용하여 나타난다. 그림에서 보이듯 맨 위 왼쪽이나 아래 오른쪽의 작은 색 삼각형은 ≤ 5% 방식의 분기율을 나타낸다. (역으로, 주된 방식은 분기율이 ≥ 95%이다.) 양성자나 알파 방출을 의미하는 작은 삼각형들은 항상 맨 위 왼쪽 구석 (첫번째 2개의 상자)에 있다. β^- 방출이나 자발핵분열에 대한 삼각형은 항상 오른쪽 아래에 있다. ε/β^+ 또는 Iγ 를 나타내는 삼각형은 주된 방식에 따라 왼쪽 위나 오른쪽 아래에 나타날 수도 있다. ε/β^+의 경우, 주 방식이 알파 또는 양성자 방출인 경우, 빨간 삼각형이 오른쪽 아래에 있다.

그렇지 않을 경우, 빨간 삼각형은 왼쪽 위 구석에 있다. 이성체 전이 Iγ에 대해, 주 모드가 알파 또는 양자 붕괴이거나 ε/β^+라면 백색 삼각형이 오른쪽 밑바닥에 있다. 아니면 위편 왼쪽 구석에 있다. 클러스터 방출은 항상 오른쪽 구석 꼭대기에 있는 작은 삼각형으로 나타난다. 그러므로 작은 삼각형의 위치는 다음과 같다:



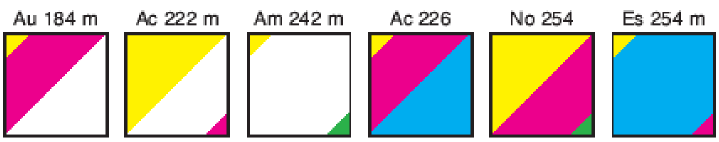
If the branching ratio of the minor mode is in the range 5 – 50% (implying a branching ratio for the major mode in the range 50 – 95%), the box is divided into two by a diagonal connection the lower left and top right corners. The location of the large triangles is similar to that described above.

비주류 모드의 분기 비율이 범위 5 - 50% (50 - 95% 범위의 주 모드 분기율 포함)인 경우에, 상자는 오른쪽 위 와 왼쪽 아래를 대각선으로 연결하여 두 개로 분할많된다. 큰 삼각형의 위치는 위의 설명과 유사하다.



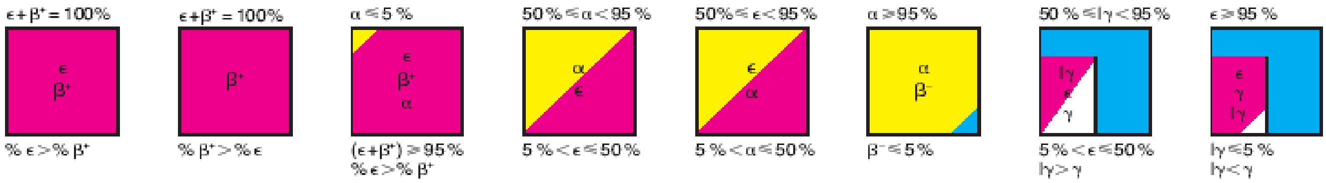
In some cases, three decay modes are possible. Some examples are shown below.

어떤 경우는 3개의 붕괴 방식도 가능하다. 몇몇 보기가 아래에 있다.

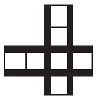


Examples:

예:



The symbols for the particle emitting decay modes are arranged according to branching ratio with the highest branching ratio first, followed by γ-quanta and conversion electrons. The data for the isomeric decay have been arranged corresponding to the branching ratio of the decay mode. β-delayed particles or fission (βn, βp, βsf) precede or follow the γ-quanta according to the relative intensities. For a given type of radiation the sequence of the energies corresponds to the relative intensities (in decreasing order) of the respective radiation. In case of β-decay a slightly different rule is used (see below).		입자를 방출하는 붕괴 방식의 기호는 분기율에 따라 나열되었는데, 가장 높은 분기율이 처음에 오고, 그 다음에 γ-양자와 전환 전자들이 온다. 이성체 감퇴 데이터는 붕괴 방식의 분기율에 대응하여 나열되었다. β-지연 입자 또는 분열(βn, βp, βsf) 가 그 상대적 강도에 따라 γ-양자 앞 또는 뒤에 온다. 주어진 유형의 방사선 에너지 순서는 각 방사선의 상대적 강도(점점 감소되는 순서로 나열)에 해당한다. β-붕괴의 경우는 약간 다른 규칙이 사용된다. (아래 참조)
Points indicate further transitions of the same type with lower intensities.	…	이 점들은 낮은 세기를 지닌 동일한 유형이 후에 좀 더 전이할 것을 나타낸다.
<u>Energies</u> are given in keV for γ-quanta, in MeV for all kinds of particles. A radiation symbol without energy value indicates that the radiation occurs but the energy has not been measured.		에너지는 γ-입자에 대해 keV로 주어지고, 모든 입자에 대해서는 MeV로 주어진다. 에너지 값이 없는 방사선 기호는 방사선은 방출되지만 에너지가 측정되지는 않았다는 것을 나타낸다.
Endpoint energy of the most abundant β-transition. In case further transitions with higher energies exist, the second number corresponds to the hightest endpoint energy observed.	β^+ 2.7 … β^- 1.2; 1.9…	가장 많은 β-전이의 끝점 에너지를 나타낸다. 고에너지를 가진 전이가 나중에 더 일어날 경우, 두 번째 숫자는 측정된 가장 높은 끝점 에너지이다.
β-transitions with known energies, for which the sum of their abundances is less than 1%.	β^-… β^+…	알려진 에너지를 갖는 β- 전이이며, 각 존재도의 합은 1% 미만이다.
Electron capture is specified only, if it is more probable than β^+-decay.	ε	β^+-붕괴보다 전자 포획의 가능성이 더 큰 경우에만 특별히 표시한다.
Particle energies listed according to decreasing probabilities of the respective transitions. At least one energy is given, even if the abundance of the most prominent group is less than 1%.	α 3.75, 4.43… p 1.56 βp 4.5	입자 에너지는 각각의 전이에서의 감소율에 따라 나열되었다. 비록 가장 현저한 그룹이 1% 미만이라 할지라도 적어도 한 개의 에너지가 주어진다.
Energies of the strongest γ-quanta arranged in order of decreasing intensities. Intensities less than 1% are given in brackets.	γ 815; 1711… γ (1340)	가장 강한 γ-양자의 에너지는 세기가 감소하는 순서로 배열되었다. 1% 미만의 강도는 괄호 속에 나타냈다.
γ-Energies followed by an asterisk denote transitions after β-delayed particle emission.	γ 815*	별표가 쳐진 γ- 에너지는 β-지연된 입자 방출 후에 전이가 일어났음을 나타낸다.
Several γ-quanta of unknown intensities within the energy interval 291-1319 keV.	γ 291-1319	에너지 간격 291- 1319 keV 내에서 미지의 강도를 가진 g- 양자.
Conversion electrons are specified only if they are more abundant than the γ-quanta. Energies are not quoted.	e^-	전환 전자는 g- 양자들보다 더 많아야만 지정된다. 에너지는 인용되지 않는다.
Cross Sections All cross sections are given in barn (10^{-24} cm^2) and refer to reactions with thermal neutrons (0.0253 eV).		**단면** 모든 단면은 '반' (barn= 10^{-24} cm^2)으로 표시되고, 열 중성자 (0.0253 eV)를 가진 반응이 있음을 나타낸다.
Cross section for the (n, γ) reaction. If two values are given, the first refers to the formation of the product nucleus in the metastable, the second to the formation in the ground state.	σ	(n, γ) 반응에 대한 단면을 나타낸다. 값이 두 개 주어진다면, 첫 번째 값은 준안정 상태에서 핵 생성물이 형성됨을 나타내고, 두 번째 값은 기저 상태에서의 형성을 나타낸다.
Fission cross section	σ_f	분열 단면
(n, p) cross section	$\sigma_{n,p}$	(n, p) 단면
(n, α) cross section	$\sigma_{n,\alpha}$	(n, α) 단면
Absorption cross section	σ_{abs}	흡수 단면
Additional Symbols and Abbreviations Chain yield (%) for the thermal neutron fission of U235 (above) and Pu239 (below) the arrowed line.	↖ 1.92 0.73	**추가 기호 및 약어** U235 (위의 숫자)와 Pu239(아래 숫자)의 열 중성자 분열에 대한 연쇄반응률 (%)은 화살표선으로 나타낸다.

Nuclides with a closed neutron or proton shell are characterized by heavy horizontal or vertical lines.		닫혀있는 중성자 또는 양성자 껍질을 가진 핵종은 굵은 수직선과 수평선으로 특징을 표시한다.
The symbols “m” and/or “g” indicate that the metastable and/or ground state of the daughter nuclide is populated, respectively. The symbols are presented in order of decreasing probability. Branches with probabilities less than 5% are not shown. Subscripts on “m”, e.g. m_1, m_2, are used to denote different metastable states (with m_2 being a higher energy state than m_1).	m; g	"m" 그리고/혹은 "g" 기호는 딸 핵종의 준안정 그리고/또는 기저 상태가 각각 측정되었음을 나타낸다. 이 기호들은 확률이 감소하는 순서대로 나열되었다. 5% 미만의 확률을 가진 가지들은 표시하지 않았다. 상이한 준안정 상태들을 표현하기 위해 "m"의 아래 첨자, 예를 m_1, m_2를 사용했다. (m_1보다는 m_2가 에너지 상태가 더 높다.)
Data or assignment uncertain.	?	불확실한 자료나 해결되어야 할 문제
Nanosecond, microsecond, millisecond, second, minute, hour, day, year.	ns, μs, ms, s, m, h, d, a	나노세컨드, 마이크로세컨드, 밀리세컨드, 초 분, 시간, 일, 년

Arrangement of Symbols and Data

기호와 데이터의 배열

Elements

symbol of the element
standard atomic weight based on C 12 = 12

absorption cross section for thermal neutrons (barn)

원소들

원소기호
C 12 = 12에 근거하는 표준 원자량

열 중성자 에 대한 흡수 단면(barn)

Stable Nuclides

symbol of the element, number of nucleons
abundance in naturally occuring element (atom %)

(n, γ)-cross sections for the formation of the metastable and the ground state of Te 127 by thermal neutrons (barn)

안정한 핵종

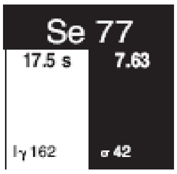
원소기호, 핵자의 수
원소의 자연 발생률 (원자 %)

열 중성자 (barn)로 나타낸 Te 127의 준안정상태와 기저 상태 형성에 대한 (n, γ)-단면

symbol of the element, number of nucleons

left hand side: half-life of metastable state;
γ-energy (keV) of the isomeric transition

right hand side: abundance in the natural element (atom %)
(n, γ)-cross sections for the thermal neutrons (barn)



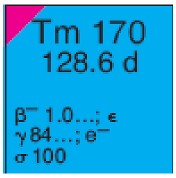
원소기호, 핵자 수
좌측: 준안정 상태의 반감기;
이성체 변이의 γ-에너지 (keV)

우측: 자연적 원소 존재율 (원자 %)
열 중성자 (barn)에 대한 (n, γ)-단면

Unstable Nuclides

symbol of the element, number of nucleons
half-life

modes of decay, endpoint energy of β⁻-radiation (MeV)
γ-energy (keV), conversion electrons,
(n, γ)-cross section (barn)



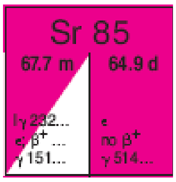
불안정한 핵종

원소기호, 핵자 수
반감기

붕괴 방식, β⁻-방출의 끝점 에너지(MeV)
γ-에너지 (keV), 전환전자
(n, γ)-단면(barn)

symbol of the element, number of nucleons
half-lives

both states decay by electron capture; the metastable state decays to the ground state
with a branching ratio for Iγ in the range of 50% – 95%



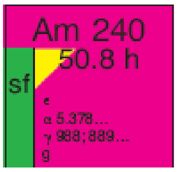
원소기호, 핵자 수
반감기

전자 포획에 의한 붕괴의 두 상태;
준안정 상태로부터 기저 상태로
Iγ 에 대한 50% - 95% 범위 내의 분기율

symbol of the element, number of nucleons

left hand side: spontaneous fission isomer, T < 0.1 s

right hand side: decay data of the ground state
"g" indicates that the daughter Pu 240g is formed to at least 95 %; a population of Pu 240m up to 5% cannot be excluded

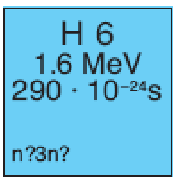


원소기호, 핵자 수

좌측: 자발핵분열 이성체, T < 0.1 s

우측: 기저 상태의 붕괴 데이터
"g"는 딸 Pu 240g가 적어도 95%까지 생성된다는 것을 나타낸다.
5%의 Pu 240m의 존재를 배제해서는 안 된다.

where emission of a particle results from a resonance state in an unstable nucleus, both the resonance width Γ (MeV) and the half-life $T_{1/2}$ are given



불안정한 핵에 있는 공명 상태의 결과로 입자가 방출될 때,
공명폭 Γ (MeV) 와 반감기 $T_{1/2}$ 둘 다 표시한다.

European Commission – Joint Research Centre – Institute for Transuranium Elements
Title: The Karlsruhe Nuklidkarte Database
Author(s): Christophe Normand
2007 – 33 pp. – 21.0 x 29.7 cm

Abstract
The interest in nuclear applications and the development of nuclear databases led to a new edition of the Karlsruhe Nuklidkarte in 2006. To smooth the progress of future updates and in view to release an electronic version of the chart, an electronic database was created. One major advantage of an electronic version is the possibility to intercompare data with other well-established international nuclear databases, such as the European JEFF database. In this framework, a collaboration with the NEA databank/JEFF project was initiated. The extended capacity of such a database, compared to the paper based version, allows improving significantly the amount of data featured in the database, with quantities such as spin or parity.

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